LEVEL II

AD A074824

AD

DDC
RECEIVED
OCT 10 1979
E

(18) AMMRC (19) TR-79-44

(6) PHOSPHONITRILIC FLUOROELASTOMER COATED FABRICS FOR COLLAPSIBLE FUEL STORAGE TANKS.

(12) 172

(11) JUL 79

FIRESTONE TIRE & RUBBER CO.,
CENTRAL RESEARCH LABORATORIES
1200 FIRESTONE PKWY, AKRON, OH 44317

(9) FINAL Rept. 1 Feb 78 - 30 Mar 79

(15) CONTRACT NUMBER DAAG46-78-C-0006

Approved for public release; distribution unlimited.

(16) 1L 163102.D071

(10) Richard W. Sicka
George B. Mitchell

DDC FILE COPY

79 10 10 005

Prepared for

ARMY MATERIALS AND MECHANICS RESEARCH CENTER
Watertown, Massachusetts 02172

370 976

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Mention of any trade names or manufacturers in this report shall not be construed as advertising nor as an official indorsement or approval of such products or companies by the United States Government.

DISPOSITION INSTRUCTIONS

Destroy this report when it is no longer needed.
Do not return it to the originator.

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DDC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

(12)

REPORT_____

PHOSPHONITRILIC FLUOROELASTOMER COATED FABRICS FOR COLLAPSIBLE FUEL STORAGE TANKS

Richard W. Sicka and George B. Mitchell
Firestone Central Research Laboratories
The Firestone Tire and Rubber Company
Akron, OH 44317

30 March 1979

Final Technical Report
Contract Number DAAG46-78-C-0006

Prepared for:

U. S. ARMY MATERIALS AND MECHANICS RESEARCH CENTER
WATERTOWN, MASSACHUSETTS 02172

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AMMRC TR 79-44	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Phosphonitrilic Fluoroelastomer Coated Fabric for Collapsible Fuel Storage Tanks		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard W. Sicka George B. Mitchell		8. CONTRACT OR GRANT NUMBER(s) DAAG46-78-C-0006
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS D/A Project: 1L163102D071 AMCMS Code: 63102 Agency Accession: DAOF4788
11. CONTROLLING OFFICE NAME AND ADDRESS Army Materials and Mechanics Research Center Watertown, Massachusetts 02172		12. REPORT DATE July 1979 13. NUMBER OF PAGES 65
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Inorganic polymers
Polyphosphazenes
Phosphonitrilic fluoroelastomers
Coated fabrics
Fuel tanks
Storage tanks

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the preparation of fuel resistant coated fabric materials that are serviceable at temperatures as low as -70°F. The coated fabric materials were made from a phosphonitrilic fluoroelastomer compound coated on nylon fabric. Efforts were directed toward attainment of calenderable compounds and test evaluations of the coated fabric. High filler loaded materials proved to be better processable materials. These

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block No. 20

ABSTRACT
(cont'd)

showed good diffusion rates with test fluids (TT-S-735, Type II and Fuel S). Even better diffusion rates were seen with Arctic diesel fuel. The low temperature flexibility of the vulcanizates and coated fabric was promising for PNP-200 compounds. The seam adhesion strength and the fabric-to-rubber adhesion need to be improved before utilization of this material in tank constructions.

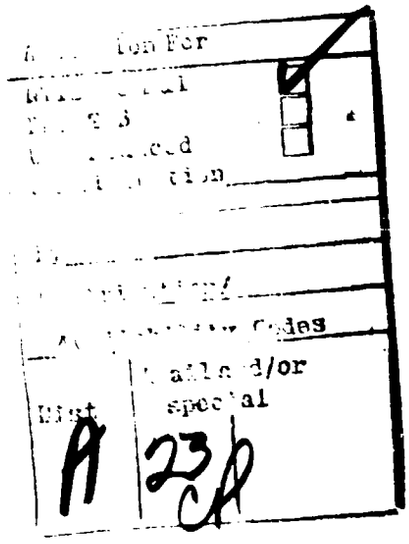

Table of Contents

List of Tables

SUMMARY

A critical need exists for fuel resistant materials which will function at temperatures of -57°C (-70°F) for application in self supporting 3,000 and 10,000 gallon collapsible fuel storage tanks.

This work is part of a continuing effort to develop materials which can form the elements of a refueling and storage system capable of service under Arctic weather conditions.

The initial phase of this work was to evaluate the PNF®-LT and PNF®-200 materials as candidates for coated fabric materials with which collapsible fuel tanks could be fabricated. Consideration of PNF®-200 was dictated in part by the need for low fuel diffusion rates. Fuel diffusion studies of the hose and tube compounds of PNF-LT used in the fuel hose contracts showed excessive rates of fuel diffusion for a coated fabric to function as a storage vessel material. Compounds of low filler content PNF-200 materials coated on nylon fabric showed promising values of low fuel diffusion rate and sufficient flexibility at low temperature (-70°F) to warrant consideration as a coated fabric candidate. Processing difficulties prevented their use as calenderable materials. Higher filler loaded materials proved to be better processable materials and showed good diffusion rates with test fluids (Type II, Fuel 6) and even better rates with Arctic diesel fuel.

Adhesion to fabric is an area requiring further study and development.

PREFACE

Investigations performed under Contract DAAG46-78-C-0006 from 1 February 1978 to 30 March 1979 are described in this final report. The primary objective of this contract was the development of phosphonitrilic fluoroelastomer vulcanizates and coated fabrics for use in the manufacture of self supporting 3,000 and 10,000 gallon collapsible fuel storage tanks with a -57°C (-70°F) capability.

This final report was prepared by the Central Research Laboratories of The Firestone Tire and Rubber Company. The work was sponsored and administered by the U.S. Army Materials and Mechanics Research Center, Watertown, Massachusetts. Dr. Robert E. Singler served as the Contracting Officer's Technical Representative.

In addition to Dr. Singler, we also wish to acknowledge Mr. Angus Wilson of U.S. Army Natick Research and Development Command and Messrs. Paul Touchet and Paul Gatza of the U.S. Army Mobility Equipment Research and Development Command for their helpful discussions relevant to the objectives of this program.

Project management at Firestone was provided by Dr. D. P. Tate, Assistant Director of Research and Dr. A. E. Oberster, Research Associate. Many co-workers at the Firestone Central Research Laboratories assisted in the compounding and testing phases of this investigation and their support is gratefully acknowledged.

1.0 INTRODUCTION

The goal of this program was the development of PNF® phosphonitrilic fluoroelastomer compounds suitable for vulcanizates and coated fabrics for use in the manufacture of self supported 3,000 and 10,000 gallon collapsible fuel storage tanks. The military specifications MIL T-52573 and MIL T-43431 (ref. 1,2) served as guidelines except that a -57°C (-70°F) capability was desired. These tanks should satisfy the Army material requirements for refueling operations in the Arctic.

The U.S. Army Mobility Equipment Research and Development Center has sponsored earlier contract efforts for the development of PNF® fuel hoses (ref. 3, 4, 5). The first investigation (Contract DAAK02-73-C-0464) showed that fuel hoses could be fabricated from PNF-200 by a plied calendered sheet process. The hoses produced were not sufficiently flexible at -70°F (ref. 3). The second study (Contract DAAG53-75-C-0187) utilized a modified PNF®, PNF®-LT which had better low temperature flexibility. This effort resulted in a hose with suitable flexibility when constructed of plied calendered sheets. The third program developed extrudable compounds for producing collapsible and suction type fuel hoses with hand wrapped covers. Large lengths of collapsible and suction hose were manufactured on Contract DAAK70-76-C-0239 and are under field test and evaluation in the Arctic.

The U.S. Army Materials and Mechanics Research Center recognized the need for collapsible fuel storage tanks capable of service at low temperatures and the potential offered by phosphonitrilic fluoroelastomers, as fuel resistant, extreme low temperature flexible coated fabric materials. The result is their support of this contract to develop PNF coated fabric materials.

PNF coated fabrics were prepared and examined by A. Wilson of Natick Laboratories for fire resistance comparison to MUST shelter coated fabric (ref. 6). MUST is an acronym for "Medical Unit Self Contained, Transportable." Although the current MUST shelter fabric uses commercial fire resistant rubbers, polychloroprene-top coated with chlorinated polyethylene, the Army experienced field incidents exposing the shelters to fire. A. Wilson cement coated PNF phosphonitrilic fluoroelastomer onto polyester fabric to prepare MUST-equivalent (14.8 oz/yd^2) material. The phosphazene coated fabrics had a higher resistance to burning than currently used materials. The excellent low temperature properties of the PNF coated fabrics were also exhibited. Adhesion properties to fabric were found to need further development.

Collapsible fuel storage tanks have a long history of development (ref. 7, 8, 9, 10, 11, 12, 13) and include storage reservoirs of 5,000 barrel capacity. Early programs on design and development of such collapsible storage reservoirs have established design criteria that include water and environmental resistance of the material in addition to resistance to the aromatic content of the fuel. Further, the wide range of temperature requirements for service were expanded to include service, especially deployment in temperatures down to -70°F. Current materials have limited capability to -25°F.

Testing of POL tanks at the U.S. Army Tropic Test Center, Fort Clayton, Canal Zone, have identified (ref. 7) design and material problems associated with storage of fuels. Diesel fuel was more destructive to tank material than storage of JP-4. Design/material problems include rapid deterioration of the exterior coating allowing solar radiation and rain to attack the fabric and fuel. The seams appear to be a source of fuel leakage.

Fuel acidity increases in pH from 7.2 to 3.8 was suspected to be the major cause of degradation and was attributable to ultraviolet radiation and moisture.

Table 1 presents the desired properties of coating compounds and Table 2 presents the properties required for a collapsible fuel tank coated fabric. Low temperature flexibility, elongation, and fuel contamination values are lowered while the retained tensile properties have been increased over the MIL T 52573C specification.

Table 3 gives a summary of the coated fabric properties and vulcanizate properties for two ranges of filler loading in PNF-200 formulations.

Generally, the fuel diffusion values are seen to be close to the desired values. Very low (< 0.01) values are observed in coated fabric which has used a heavy surface treatment. Fuel diffusion through PNF-200 vulcanizates are about 0.09 fl oz/sq ft 24 hrs for high filler levels and about 0.18 fl oz/sq ft 24 hrs for low filler level vulcanizates. The high filler vulcanizates show good retention of tensile properties on fuel aging at 160°F for 14 days. The vulcanizates also show good values for existent gum.

2.0 INVESTIGATION

2.1 Polymer

PNF-200 is a semi-inorganic fluoroelastomer commercialized by The Firestone Tire & Rubber Company. This phosphonitrilic fluoroelastomer has a service temperature range of -70°F to 350°F and possesses a unique combination of properties including solvent resistance and low temperature flexibility, high temperature stability and excellent mechanical properties.

PNF has excellent resistance to hydrocarbon fluids, lubricating oils and fuels. PNF is not suitable for use in oxygenated solvents such as ketones, ethers and alcohols. PNF-200 is useful for continuous service in most environments at 350°F. It can be applied for intermittent service at temperatures in the range of 400-500°F (ref. 14).

Typical PNF compounds have limiting oxygen indices in the range of 55-60. This makes PNF a candidate for use in elastomeric flame resistant coating and coated fabrics. A. Wilson has examined briefly the smoke and flame properties of PNF coated fabrics (ref. 6).

PNF-LT is a phosphonitrilic fluoroelastomer containing pendant fluoroalkoxy groups with a reduced level of fluorine content in the polymer. This illustrates one of the many variations possible with the polyphosphazene system. Such a modification lowers the Tg of the polymer at the expense of solvent resistance.

Table 4 shows the properties of a nylon fabric which has been used by Firestone in the preparation of other coated fabric tank material. This material meets or exceeds the properties desired in MIL T-52573C. Table 5 presents the physical property data on the various PNF polymers used in this program.

2.2 General Approach

The initial effort of this program concerned the selection of the type of PNF polymer: PNF-LT versus PNF-200. Initial compounding and testing was directed to evaluate the fuel diffusion and low temperature flexibility. Following this selection, additional GFM (government furnished material) was obtained and the questions of diffusion, processability and retention of properties on fluid aging received the most attention in further compounding.

Small mixes sufficient to prepare tensile ring specimens and to permit about 2 each 6" x 6" coated fabric samples to be built from a formulation were used to establish properties.

Large batches were Banbury mixed and calendering of stock and fabric was then attempted for the most promising mixes.

2.3 Experimental Details

2.3.1 Instruments

1. Laboratory Rubber Mills:

   a. 2" x 6", L. Albert and Son, Model A-6974 Capacity: ca. 100 g of PNF stock.

   b. 6" x 12", Farrel-Birmingham, Inc. Model 4467. Capacity: ca. 2 lbs. of PNF stock.

   c. 10" x 12" Farrel-Birmingham, Inc.

   d. 12" x 20" Farrel Co., Div. USM Corp., Inc. Model A1500. Capacity: ca. 25 lbs. PNF compound.

   e. 3" x 7" Farrel-Birmingham Co. Model A1821. Variable speed, individual roll drive. Capacity: ca. 120 g PNF stock.

2. Calender, 4 roll inverted "L" 6" x 13". Variable speed. Capacity: ca. 10" wide sheet with roll guides in place.

3. Brabender Mixer, Model PL-V150. C. W. Brabender (CWB) Instruments, Inc. Capacity: ca. 120 g of PNF stock.

4. Banbury Mixer, Model "BR" A1548 Farrel Co., Div. of USM Corp, Inc. Capacity: ca. 2,200 g of PNF stock.

5. Laboratory Balances
   a. Mettler, Model PN2210, used for weighing pigments and polymer for small batches. Capacity: 2,200 g, $\pm$ .005 g.

   b. Toledo, Model 3710, used for weighing of pigments and polymer for large batches.

6. Instron, Model No. 1130, The Instron Corp. Used for stress-strain measurements. The instrument is interfaced with a Hewlett Packard Computer for computations of stress-strain data using micro-tensile rings. ASTM D3196.

7. Shore A Durometer. Shore Instrument and Mfg. Co., Inc.

8. Gehman Torsional Wire Apparatus. Wallace Test Equipment, Testing Machines, Inc. Amityville, NY.

9. Forced Air Oven, Blue M Electric Co., for heat aging polymer and post curing vulcanizates and coated fabric.

10. C. W. Brabender Electronic Plasti-corder Torque Rheometer, Model EPL-V751.

2.3.2 Mixing Techniques

In Brabender mixes, the polymer is added to the mixer and is consolidated at low speed (10 rpm) for about one minute. The reinforcing filler is then added while mixing at medium speed (40-60 rpm). Non-reinforcing fillers, MgO and stabilizer which are blended are then added. Complete addition of fillers occurs within about six minutes. The mixer is then run at about 110 rpm until an integrated torque of 20,000 meter-gm min. is attained or about 15 minutes total mix time. The mix is then dumped. Curing agent is then added to the masterbatch banded on a mill. Ambient temperature mills were generally used.

Better results of mixing were obtained with cooled mixing chambers.

Banbury mixing followed much the same procedure above: Cooling water on maximum flow.

0 minutes-load polymer, speed: slow (77 rpm)
2 minutes-add fillers
7 minutes-add stabilizer masterbatch
15 minutes-dump mix

To obtain as low a mix temperature as possible additional cooling was supplied to the mixing chamber walls by dry ice. Temperatures as low as 150°F (65°C) were obtained.

The curative was added on a two roll mill with cooling water running in the cored rolls in order to maintain

a low temperature.

The several batches of a given formulation were mill blended together on the 10" x 20" Farrel mill.

2.3.3 Calendering Techniques

Initial test samples were prepared from small Brabender compounds by sheeting material on a vari-drive 3" x 7" mill where roll speed could be matched as on a calender. Sheets 0.020" thick and less were prepared and coated fabrics formed in 6" x 6" cavity molds suitably shimmed to appropriate thicknesses. These samples served as initial fuel diffusion and low temperature flexibility specimens.

A number of the compounds were difficult to handle by this procedure as the compounds did not have suitable green strength or tended to retract after release from the roll of the mill.

Late in the program a technique was developed which overcame this difficulty. This involved applying a sheet of .005" thick polyester film to the fast roll of the mill by means of double coated adhesive tape. The stock could then be worked on to the polyester and removed readily from the mill roll along with the polyester carrier sheet. Trimming the stock and polyester carrier to mold size provided convenient preparation of even difficultly processable materials.

Calendering on the 6" x 13" four-roll inverted "L" calender was accomplished to form 60 mil thick x 6" wide sheets which were roll-wrap cured between polyester film or metal shim stock for improved sheet finish and release. The most promising processable, yet impermeable to test fluid, stocks were calendered to sheets .025" thick x 10-1/4" wide in lengths to 25 feet. Initial attempts to calender the PNF stock into the 2 x 2 basket weave nylon fabric met with difficulty primarily due to the preferential adhesion of the stock to the calender rolls instead of the surface agent treated fabric.

This difficulty was surmounted by the use of carrier film material. The fabric was calendered into one sheet of .025" thick PNF stock and then the second surface of the fabric was calendered with stock on a second pass.

In each case carrier film material was interposed between the PNF stock and calender roll surface.

2.3.4 Physical Test Methods

Test specimens were prepared from sheeted samples by press curing 50 mil thick x 3" x 3" specimens. Coated fabric specimens were prepared in a 6" x 6" cavity mold. Calendered stock and coated fabric were wrap cured.

1. Stress-strain - ASTM D3196. Specimens were cut from 50 mil thick x 3" x 3" vulcanizate sheets.

2. Shore "A" hardness - ASTM D2240. Tests were made on plied vulcanizate.

3. Gehman low temperature measurements - ASTM D1053. Specimens 1.5" x 0.125" of vulcanizate were cut from sheets. An IBM 1130 computer was programmed for computation and print-out of Gehman data and graphs. Specimens 1.5" x 0.250" of coated fabric were cut from samples and similarly tested by ASTM D3388.

4. Fuel diffusion tests. Tests were conducted in accordance with para. 4.6.2.2.2 of specification MIL T-52573C with coated fabric samples and vulcanizates of promising PNF stocks.

5. Weather-O-Meter Atlas 18-WR used for accelerated aging of specimens with Cam No. 47, 18 hours of light and water in a 102 min. light and 18 min. water spray cycle followed by a dark period of 6 hours. Samples were aged for 500 hours total light. Black panel temperature 63° ± 5°C (50 ± 5% relative humidity) is obtained when illuminated.

6. Existent gum test performed in accordance with para. 4.2.1.1.1 and 2 of MIL T-52573C and ASTM D381.

2.3.5 Compounding

The initial phase of this program involved the evaluation of PNF-LT and PNF-200 materials as candidates for coated fabric materials with which collapsible fuel tanks could be fabricated. Fuel diffusion studies of the hose and tube compounds of PNF-LT used in the fuel hose contracts (ref. 3,4,5) showed excessive rates of fuel diffusion for a coated fabric to function as a storage vessel material. After consideration of the diffusion rates of TTS-735, Type II fuel through coated fabric samples prepared with PNF-LT, PNF-200 and blends thereof (see Tables 13, 14, 15), it was determined to confine the

remainder of the program to development of coated fabric material with PNF-200 based on its better diffusion characteristics. The low temperature flexibility of low filled PNF-200 compounds may be acceptable in the format of a coated fabric. Studies of low temperature torsional stiffness ratio provided evidence for this selection.

Table 6 presents the results of compounding each of the PNF-200 polymers with a typical low filler content vulcanizate and also a high filler content formulation. Low filler content materials generally show higher stress-strain properties, while the high filled materials exhibit better processability.

Various filler materials were examined at low filler loadings (15 phr). These include surface treated silica fillers, (Tullanox 500), surface treated anhydrous aluminum silicate, Burgess KE and platey fillers such as talc (Mistron Vapor). The compounds attempted are presented in the Tables 6 through Table 12. Table 3 summarizes the leading formulations of PNF-200. The fuel diffusion rates for similar compounds were determined and are summarized in Tables 13 through 15. The PNF-LT stocks show fuel diffusion rates which are markedly higher than similar compounds based on PNF-200. Blending in various amounts of PNF-200 did not improve the diffusion rate values significantly. PNF-LT was not considered further in the compounding program. The fuel diffusion rates of the early PNF-200 compounded materials are 0.07 fluid oz/sq ft/ 24 hours. This is close to the desired value but requires improvement. Fuel diffusion rates of coated fabric as low as < 0.01 were obtained, (see Table 29).

Table 16 and 17 presents the results of G.C. analysis of the residual fuel in the test cups after a coated fabric diffusion rate determination. The PNF-200 stocks showed the lowest loss of material to be the iso-octane. The PNF-LT stocks had high losses of iso-octane from the fuel mixture.

The trend of weight loss of benzene > toluene > xylenes >> iso-octane was seen for PNF-200 stocks. For PNF-LT the trend was the same but the magnitude of iso-octane loss was larger. Blending of PNF-200 into PNF-LT stocks reduced the iso-octane losses while the aromatic constituent losses were still nearly double or more than PNF-200 alone.

P. Touchet of MERDC evaluated several coated fabric (ref.) samples as seen in Table 18. One can see that on the combined balance of fuel diffusion rate, tensile strength elongation and torsional stiffness ratio, formulation R211922 was ahead. Unfortunately, it is very difficult tc process since it is quite nervy and sticky. R211924 seemed to offer some processability advantages and was examined further.

Table 19 through 24 present formulations which attempted to address the processability problems from various aspects. First this was studied by increased clay or filler loading and then by low molecular weight silicone process aid, HA-2, addition. Also, a fluorosilicone process aid, FSE262U, addition was used. Some slight improvements in release from mill rolls was seen for the low levels of process aid addition.

An alternate approach was considered, namely thermal aging of the polymers. This appeared to offer some improvement in the processability of PNF-LT in the hose building programs previously mentioned. First attempts with this approach are presented in Tables 21 and 22 where a silicone process aid is included in the formulation. Since the diffusion results with these formulations were so poor (i.e., diffusion rates > 0.2 fl. oz./sq. ft. - 24 hours), a second series of compounds without the use of the silicone process aid was initiated as shown in Table 23 and 24.

The stress-strain properties, tensile strength, appeared to improve slightly over the previous "process aid" series. The high filler approach seemed to offer the processability advantage, such as R211924 in Table 11.

Several large mixes were prepared in a Banbury "BR" size mixer with the high filler level loading of formulations similar to R211924 which showed earlier good diffusion rate results. These mixes are presented in Table 25 along with some coagent additions to small samples of each batch. The coagent did increase the modulus, elongation was reduced and diffusion rate for vulcanizates was lower.

Samples of the large batches were prepared (see Table 26) and submitted to Weather-O-Meter aging using the No. 47 cam which gave a period of 18 hours of 102 min. light and 18 min. water spray cycles followed by a period of 6 hours of dark. The retention of tensile properties is quite good with only a 15-20% reduction over 500 hours of total light exposure. The R11988 vulcanizate containing a thermal stabilizer and hence a tan-yellow tint was bleached out after the exposure to light. The R211992 vulcanizate (not containing the stabilizer but additional silane) was light color to start and also lightened under light exposure.

Table 27 shows the stress-strain properties after aging R211988 in test fuel "S" at 160°F. After 14 days the tensile strength and elongation are within specification. After this first initial drop in tensile values, the change to 42 days is very small. After 42 days the tensile strength is within the range set by the specification.

Since the role of metal impurities in contact with jet fuels has an important influence on the oxidative stability of fuels such as JP-4, an analysis was conducted on several polymer samples. Copper has an especially deleterious effect on the storage stability of JP-4. This is reported to occur at low soluble copper content (< 0.3 ppm) in fuel and also in contact with copper (ref. 15).

Atomic absorption metal analysis showed the following values for PNF polymer gum prior to any compounding.

	Atomic Absorption Metal Analysis Parts Per Million (ppm)			
	Cu	Fe	Ni	Cr
PNF Polymer				
K18356 (PNF-LT)	0.01	2	none	0.1
K19736 PNF-200	0.09	0.8	none	0.07
K19861	0.08	2	none	0.08
K19862	0.09	2	none	0.09

One can see the levels to be low for copper.

The filterability of a fuel is affected by the presence of particulate matter in the fuel whether it is dirt, solidified fuel or ice, produced by low temperatures, or insoluble gum caused by aging of the fuel. The presence of insoluble gum aggravates the effect of ice on filter plugging, probably due to the fact that it provides nucleation sites for the growth of ice crystals. While filtration should remove existent gum, the event of by-passing the filters under emergency military situations exists. Therefore, the lowest existent gum values are desired.

A check of fuel contamination of the PNF-200 R211988 and R211992 compounds was conducted. Table 28 compares the values of unwashed existent gum, heptane-washed gum and stored gum residue for these compounds with the values required in MIL T-52573 and that of this contract.

One can see that very little gum is generated in the test fuel by the PNF compounds. The values determined in the tests show PNF materials are well below the required values.

Table 29 presents fuel diffusion rate data for a number of coated fabrics and vulcanizates. For purposes of comparison the fuel diffusion rates of current MIL T-52573C coated fabric was measured with both "Fuel δ" and Type II fuel. One type of material appeared to pass the requirements with 0.037 and 0.05 fl oz/sq ft - 24 hours. The PNF-200 compounds appeared to have diffusion rates which were close to that desired, but depended upon fabric surface treatment.

The lowest diffusion levels were seen with purified PNF-200 polymer and a thick surface treatment to the nylon. This was too rigid to meet flexibility requirements. A lighter coating of fabric treatment looked promising (TX13 and TX14).

The nature of fabric surface treatment was explored further as shown in Table 30 where various treatments were applied to the fabric. The Thixon material showed the best results. Table 31 shows the effects of these treatments upon the breaking strengths of the coated fabrics and the retention of this property with aging in water and test fuel C. The best breaking strengths were seen with a Fluorel 5150 treatment. However, these showed the greatest loss in water aging. Thixon 300/301 treated fabric had the best overall aging property.

Table 32 presents several mixes with different filling factors in a measuring head mixer. Some exceptionally good tensile strength and elongation values are seen for several mixes where the temperature of the mix was maintained at a low values 97°C or less.

This procedure was used in later Banbury mixes but the tensile strengths were not as high as those realized here.

The adhesive peel strength was examined for coated fabrics which had various surface treatments. Efforts were directed to attempt to attain the adhesive peel strength of about 20 ppi.

The values shown in Tables 33, 34, 35 show Thixon A/B to be the best performing surface treatment. However, the value of about 9 ppi is attained with a heavy coating on the fabric. The breaking strengths are shown in Table 35 and role of temperature of cure indicates that 170°C is better for promotion of breaking strength.

Examination of fracture surfaces of tensile specimens indicated large agglomerates of stabilizer crystals were present. In an attempt to reduce this particle size of the stabilizer it was ball milled with Burgess KE clay for 24 hours and prepared as a masterbatch for the Banbury mixes to follow. See Table 26 for the masterbatch formulation. Later, examination of fracture surfaces of Banbury mixes showed a reduced size but still identifiable particles of stabilizer. This is an area requiring further study in the future.

Since large quantities of compound were needed for calendering, a number of Banbury mixes were made with formulations representing the best combination of properties: processing, diffusion rate and stress-strain. The mixes and their properties are shown in Table 37. Table 30 presents diffusion rates.

Formulations 219601 and 602 were identical except for the PNF-200 polymer batch. This entire mix was blended and labeled as 219601 so that samples could be prepared of coated fabric for shipment. The mix temperature of this series was kept low to achieve higher viscosity and greater shear mixing.

Formulation 219607 represented the best physical property formulation with low diffusion but was difficult to process as a calenderable material. It was used to prepare cement coatings on fabrics before building coated fabrics.

Earlier work with small batches of purified polymer showed some improvement in diffusion rate when compared to normal polymer. Table 38 presents this data. The polymer was purified by making a 14% PNF-200, K19861, solution in methanol, filtering, followed by coagulation in water. Based on these findings, a 9 lb. quantity of polymer was committed to a purification procedure and included in the Banbury mixes.

Formulation 219608 and 219609 were mixed and compared to evaluate the role of an additional purification step on the PNF-200 polymer. Polymer 1508-49 was obtained by dissolving polymer K19861 in methanol, 1 lb/gal, followed by dilution with one gallon of methanol. Centrifugation removed some particulate matter. The cement was coagulated in deionized water, collected and vacuum dried. Only small differences were seen between the two formulations in original properties and even after aging in Fuel S for 14 days at 160°F as seen in Table 39. The diffusion rates for R219608 and R219609 are nearly identical for both vulcanizates and coated fabric.

Table 41 lists the breaking strengths of coated fabrics prepared from the above Banbury mixed stocks with different fabric surface treatments, Thixon 300/301 and Fluorel 5150. The breaking strengths were obtained on water aged fabrics after 7 days at 160°F. Here the stock 219609 with purified polymer shows improved properties compared to 219608. The Fluorel 5150 treated fabrics showed slightly better properties than the Thixon except for the purified polymer stock 219609.

A roll wrap cure procedure was examined to determine if similar physical properties could be obtained to press cured materials. Table 42 shows the results of a calendered length of material wrapped around an aluminum tube interleaved with steel skim for heat transfer and surface finish purposes. Samples were taken every six inches along the length and tested. Comparison is made to press cured material. One can see only a very small difference in properties.

This establishes a production-type of procedure which was used to prepare calendered and cured stock and also coated fabric material. Lengths of seam were also prepared in this manner.

A number of adhesion pads were prepared to establish initial seam adhesion peel strengths. Calendered fabric (uncured) was plied and press cured with a 1" strip of Holland cloth at one end to permit ready gripping in a tensile test machine. Initial strengths of about 9.0 ppi were obtained; however, there was ready migration of the tear to the fabric and a fabric-to-rubber strength of about 6.0 ppi was observed. When additional adhesion promoters were used on fabric and seam, slightly higher values of peel strength were seen as presented in Table 43.

This area of fabric adhesion and seam strength adhesion needs further study and improvement.

2.4 Material Shipments

On February 1, 1978 the contractor acknowledged receipt of:

10 lbs. of PNF-LT K18356
10 lbs. of PNF-200 K19736

as a partial shipment from Contract DAAG46-78-M-1204.

After a decision was reached in a May 24, 1978 meeting with the Contracting Officer's representative, Dr. Robert E. Singler, the shipment of 80 lbs. of PNF-200 was made June 15, 1978 and receipt of

8 lbs. of K19736)
62 lbs. of K19861) PNF-200
10 lbs. of K19862)

was acknowledged.

Also, 40 lbs. of Government Furnished Material as PNF-200 compounded gum elastomer stock (approximately 50% PNF-200) was received by this contractor as 18 lbs. of R211,988 and 22 lbs. of R211992 compounded elastomer stock on October 31, 1978 as per purchase order DAAG46-78-M-1256.

Under this contract shipment of materials to AMMRC included:

20 lbs. K19861 PNF-200 Polymer - 10 October 1978.

Item 0001AB

1. 18 square feet of PNF-200 coated fabric.

R219601 9-3/4" x 73" x 55 mil	4.9 sq. ft.
R219601 9-3/4" x 72" x 55 mil	5
R211992 10" x 39" x 50 mil	2.7
R211992 10" x 43-1/2" x 56 mil	3.0
R211992 9-1/2" x 59" x 56 mil	3.9
	19.6 sq. ft.

2. 4 square feet of PNF-200 cured compound.
   Press cured.

8 each 6" x 6" x .075" R211992 8 each 6" x 6" x .075" R219601	4 sq. ft.

   Wrap cured material.

1 each 6" x 48" x .065" R219608	3.25 sq. ft.
1 each 6" x 30" x .065" R219601	
	7.25 sq. ft.

3. PNF-200 seam adhesion samples 6 ft. length
   10" wide seam x 51" long wrap cured, R219601
   5 each 8" x 10" press cured adhesion pads, R211988

1 each 4" x 10" R211988 1 each 4" x 10" R219601	
	8.25 ft. of seam material

Also shipped were 12 each 6" x 6" x .078" ASTM sheets of R211988, R211992, R219601 and R219607.

3.0 Conclusions

1. PNF-200 has better fuel diffusion properties than PNF-LT.

2. Diffusion test results indicated that a diffusion barrier layer was not needed.

3. The low temperature flexibility of the low filler content PNF-200 compounds appears adequate to meet service requirements at -70°F.

4. Additional development is required to improve adhesion-to-fabric substrate.

5. Processability was not improved by attempted thermal degradation of the PNF-200 polymer at 300°F. The PNF-200 polymer DSV or ML4-212 did not change very much even after 12 hours aging. (See Table 21)

6. Silicone and fluorosilicone process aids proved unsatisfactory because fuel diffusion rates were adversely affected.

7. The breaking strengths of the coated fabric were less than the original material. Several factors could contribute to this: a) the fabric may be mechanically damaged in the fabrication process, b) chemically damaged by the fabric surface treatment, and c) the PNF-200 compound may contain small amounts of residual fluoroalcohol (a known solvent for nylon) and contribute to early failure due to stress corrosion cracking.

8. The low temperature flexibility of PNF compounds is quite good. However, the representation of TSR (torsional stiffness ratio) does not adequately reflect the low modulus of rigidity of the PNF vulcanizates and coated fabrics. Values of modulus should also be examined at the low temperatures and not merely the ratio to the room temperature modulus.

4.0 Recommendations

1. Improve fabric-coating adhesion.

2. Consider selection of alternate fabric materials with reduced weight and increased strength.

3. Study development of stronger seam bonds.

4. Consider further processability improvement studies to promote fabric calendering at rapid speeds.

References

1. MIL-T-52573C Military Specification, Tank, Fabric Collapsible, 10,000 gallon, petroleum.

2. MIL-T-43431 Military Specification, Tank.

3. G. S. Kyker and J. A. Beckman, "Fabrication of a Fluorophosphazene Low Temperature Fuel Hose," Firestone Tire and Rubber Co., Akron, Ohio. U. S. Army Mobility Equipment Research and Development Center, Contract DAAK02-73-C-0464, Jan. 1974.

4. T. A. Antkowiak and D. M. Welvaert, "Fabrication of a Low Temperature Fuel Hose from Phosphonitrilic Fluoroelastomer," Firestone Tire and Rubber Co., Akron, Ohio. U. S. Army Mobility Equipment Research and Development Center, Contract DAAG53-75-C-0187 P00002, November, 1976.

5. T. A. Antkowiak, "Phosphonitrilic Fluoroelastomer Fuel Hose-Utilization of Extruded Tubes," Firestone Tire and Rubber Co., Akron, Ohio. U. S. Army Mobility Equipment Research and Development Center, Contract DAAK70-76-C-0239, October, 1977.

6. A. Wilson, "Fire Resistance of Phosphazene Rubber Coated Fabrics." U. S. Army Natick R & D Command, Natick, Mass. 01760. Journal of Coated Fabrics, Vol. 7 (Jan. 1978), pg. 233-37.

7. N. A. Caspero, "Development of a Hasty Bulk Fuel Storage Reservoir," Army Engineer Research and Development Labs., Fort Belvoir, VA. Interim Engineering Report, December, 1965, AD 480 260/9ST.

8. U. S. Army Tropic Test Center Staff. "Material Testing in the Tropics." U. S. Army Tropic Test Center, Fort Clayton, Canal Zone, USATTC Report No. 7602001, February, 1976.

9. R. W. Ball, Jr., "Tropic Integrated Engineering and Service Test of Tank, Collapsible Self Supporting, 5,000 BBL Capacity." Army Tropic Test Center, Fort Clayton, Canal Zone, Final Report, March 1968, AD 832124.

10. C. H. R. Kramer, R. W. Peters, "Tropic Integrated Engineering and Service Test (Tropic Retest) of Tank, Collapsible, Self-Supporting, 5,000 BBL Capacity," Army Tropic Test Center, Fort Clayton, Canal Zone, Final Report, August, 1969, AD-860 269/0ST.

11. W. L. Noll and J. W. Moran, "Summary of Elastomers/JP-7 Fuel Compatibility Test Programs from 1966 to 1972," Air Force AERO Propulsion Lab, Wright-Patterson AFB, Ohio. Summary Report, May 1973, AD 913 277/0ST.

12. M. E. Lepera, "Investigating the Elastomer Environmental Effects on the Storage Stability of Military Fuels," Army Coating and Chemical Lab., Aberdeen Proving Ground, MD, Final Report, April, 1970, AD 704707.

13. C. W. Cooper, H. T. Kemp and R. M Kell, "Elastomers for Fuel Systems Containing Microorganism Controlling Additives," Battelle Memorial Institute, Columbus, OH. Summary Report, Contract No. AF 33(657)9804, January, 1965, AD 462 148.

14. J. A. Beckman "PNF-200 Phosphonitrilic Fluoroelastomer- An Overview of Properties and Applications," Central Research Laboratories, The Firestone Tire and Rubber Company.

15. A. C. Nixon, Chapter 17 "Autooxidation and Antioxidants of Petroleum," Autooxidation and Antioxidants Vol. II, W. O. Lundberg, Editor. Interscience Publishers, a division of J. W. Wiley and Sons, NY, 1962.

16. P. Touchet, U.S. MERDC, private communication.

Glossary

Item	Description	Source
Burgess KE	Surface treated anhydrous aluminum silicate.	Burgess Pigment Co.
Chemlok 607	Adhesion promoter	Hughson Chemicals, Lord Corporation
Chemlok AP134 Chemlok AP133	Adhesion promoters for fluorocarbon rubber containing silicone, tuluene, butyl cellosolve and n-butanol.	Hughson Chemicals, Lord Corporation
Elastomag 170	High activity magnesium oxide.	Akron Chemical
FEF	Fast extruding furnace black. ASTM classification N550.	
Fluorel 5150	A bonding agent for rubber-to-metal and rubber-to-rubber for fluoroelastomers.	3M, Commercial Chemicals Div.
FSE262U	Fluorosilicone rubber compound (processing aid).	General Electric
HA-2	Silicone rubber compound (processing aid)	Dow Corning
Mistron Vapor	Ultrafine magnesium silicate pigment.	Cyprus Ind. Minerals Co.
Min-U-Sil	5 micron ground quartz	Penn Glass Sand Corp.
PNF®-200	A phosphonitrilic fluoroelastomer containing pendant fluoroalkoxy groups.	Firestone
PNF®-LT	A phosphonitrilic fluoroelastomer with a reduced level of fluorine in the polymer.	Firestone
phr	per hunderd parts by weight rubber.	
Silane A151	Vinyltriethoxysilane	Union Carbide
Silane A174	gamma-methacryloxypropyltrimethoxysilane	Union Carbide

Glossary (cont'd)

Item	Description	Source
Silane A1100	gamma-aminopropyltriethoxy-silane	Union Carbide
Stabilizer	Zinc II bis(8-oxyquinolate)	Southland
TAIC	Triallylisocyanurate	Allied Chemical
Test Fuel: Type II, TTS-735	60V iso-octane 5V benzene 20V toluene 15V xylenes	
Test Fuel: Type S	60V iso-octane 25V toluene 15V xylenes	
Thixon 300/301	A one coat adhesive for bonding fluorocarbon elastomers to metal. Previously designated as Thixon A/B 273.	Whittaker, Dayton Coatings & Chemicals Division
Tullanox 500	Hydrophobic fumed silica	Tulco
Vulcup 40KE	40% α, α'-bis(t-butylperoxy) diisopropylbenzene	Hercules
Water ground Mica	-325 mesh water ground mica.	C. P. Hall
Z-6020	Aminoalkyl functional silane	Dow Corning
Zeolex 23-A1100	Surface treated silica	J. M. Huber
Zonyl FSN	A fluorosurfactant, non-ionic.	DuPont

TABLE 1. DESIRED PROPERTIES OF CANDIDATE COATING COMPOUNDS

Initial		
Tensile strength, psi (min.)	1,500	
Ultimate elongation, % (min.)	200	
Properties after immersion in test fluid TT-S-735, Type II at 160°F for 14 days		
Volume change % (max.)	40	
% Retention of initial tensile strength (min.)	60 % (or 900 psi)	
Properties after immersion in distilled water at 160°F	14 days	42 days
Volume change %	record	record
% retention of initial tensile strength.	60%(min.) (900 psi)	50%(min.) (750 psi)
Properties after accelerated weathering for 500 hours at 10% elongation (exterior compound).	75%(min.)(1125 psi)	
Stiffness at -70°F (after 4 days at -70°F)	Maximum of 5 times stiffness at + 73°F.	
Value (after 4 days at -70°F)	record	
Fuel contamination		
Unwashed existent gum mg/100 ml, max.	20	
Heptane washed existent gum, mg/100 ml, max.	5	

TABLE 2. DESIRED PROPERTIES OF COATED FABRIC

Weight, ounces/sq. yd.	30-50	
Thickness, mils	record	
Type II Fuel diffusion rate fluid ounces per square foot per 24 hours, max.	0.050	
Tearing strength, lbs.		
Warp, min.	35	
Fill, min.	35	
Breaking strength, lbs./in.		
Warp, min.	400	
Fill, min.	400	
Puncture resistance, lbs. min.	110	
Properties after 500 hours accelerated weathering at 5% elongation, initial tensile strength, % retained		
Warp, min.	80	
Fill, min.	80	
Low temperature (-70°F, 4 days) Crease resistance		
Appearance after unfolding	No cracking, peeling or delamination.	
Fuel diffusion rate, fluid ounces per square foot per 24 hours, max.	0.050	
Blocking test	Test specimen separates with 5 seconds.	
Coating adhesion initial lbs/in.(min.)	20	
Coating adhesion after immersion in distilled water at 160°F (lbs./in.)	14 days 10 (min.)	42 days 5 (min.)
Coating adhesion after immersion in Type II fluid at 160°F (lbs./in.)	14 days 10 (min.)	42 days 7 (min.)

TABLE 3. PNF-200 VULCANIZATE AND COATED FABRIC PROPERTIES - SUMMARY

	DESIRED PROPERTIES	LOW FILLER LEVEL FORMULATIONS	HIGH FILLER LEVEL FORMULATIONS
Diffusion Rate fl. oz./sq. ft. 24 hrs.	0.05 max	R211922 0.073-0.08	R211924 (or 988, or 608) < 0.01 to 0.11
Coated Fabric Wt.	30-50	37.8 to 55	45 to 64
Breaking Strength	400 ppi	370 ppi	240-480 ppi

Low Temperature Flexibility ASTM D 1053 G psi, Room Temperature		Vulcanizate 34 psi	ASTM D3388 Coated Fabric 1275 psi	ASTM D3388 Coated Fabric 593 psi
T_5	-70°F	-57°C	TSR -70°F 6.6	TSR -70°F 19.8
T_{10}		-60°C		
T_{100}		-67°C		
Vulcanizate Properties:				
Tensile Strength	1500	1562 to 1616		1309
Elongation, %	200%	294 to 217		140
Tensile Strength Retention-Fuel Aging	60% (900 psi) 14 days	———		91% (1192 psi)
Fuel Contamination Unwashed Existent Gum	20 mg/100ml	———		4.0 to 1.0
Heptane Washed Gum	5 mg/100ml	———		2.0 to 0.6
Processability		Poor-Fair		Fair-Good

TABLE 4. NYLON FABRIC PROPERTIES

Nylon 66

8.25 oz/sq. yd.
2x2 basket weave

Physical Properties:

Breaking Strength	Warp	480	Lbs/in
	Fill	480	Lbs/in
Tear Strength	Warp	120	Lbs.
	Fill	100	Lbs.

Finish: scoured and heat set

Yarn Description:

Type				
Warp	705 or equal	840/1	Denier/ply	Producers Twist
Fill	705 or equal	840/1	Denier/ply	Producers Twist

Yarn Construction:

Count	Warp	35-37	ends/inch
	Fill	33-35	ends/inch
Weight	8.0 - 8.5 oz./sq. yd.		
Gauge	0.0165 - 0.0195 inches		

TABLE 5. POLYMER DATA

	PNF®-LT	PNF®-200			
K Number	K18356	K19736	K19861	K19862	K19730
DSV (dl/g.)	2.77	2.62	2.3	2.26	2.29
Gel (%)	0.0	0.0	0.0	0.0	0.0
Na (wt. %)	0.013	0.0084	0.014	0.012	0.026
Cl (wt. %)	0.074	0.027	0.022	0.03	0.094
Tg °C	-76.5°C	-65°C	-65°C	-66°C	-71.5°C
M_w *	13.8×10^6	9.6×10^6	7.7×10^6	8.0×10^6	7.6×10^6
ML-4, 212°F	17.0	17.6	14.9	16.7	14.5
Amount of GFM (Government Furnished Material) obtained:	10 lbs. (Received 15 June 1978) 10 lbs. (Received 26 Oct. 1978)	10 lbs. (Received 1 Feb. 1978) 8 lbs.	62 lbs.**	10 lbs.	22.5 lbs. polymer as 40 lbs. compounded stock (18 lbs. R211,988 22 lbs. R211,992)

* Gel Permeation Chromatography data based on PNF standards (MW used in calibration).

**20 lbs. K19861 shipped to R. Singler, AMMRC 10 Oct. 1978

TABLE 6. PNF-200 POLYMER COMPARISON VIA COMPOUNDING

Formulation A. 15 phr Tullanox 500, 5 Zeolex 23, 6 Elastomag 170, 2 stabilizer, 2.5 Silane A174, 0.4 Vulcup 40KE

Formulation B. 70 phr Burgess KE, 15 Mistron Vapor, 10 Zeolex 23, 8 Elastomag 170, 2 stabilizer, 0.5 Vulcup 40KE

Polymer:	Formulation A			Formulation B		
	K19736	K19861	K19862	K19736	K19861	K19862

Monsanto Rheometer Data. T = 340°F, 1° ARC, 100 RPM Mini Die.

	R211944	-945	-946	-947	-948	-949
Scorch Time	1.8	1.7	1.7	3.2	3.3	3.6
Opt. Cure TC(90)	17.3	14.5	15.3	21.0	23.9	25.0
Min. Torque,	6.6	6.5	5.9	13.5	12.1	12.1
Torque @ 90% Cure	17.0	16.8	16.6	26.6	23.6	20.9
Max. Torque,	18.1	17.9	17.8	28.0	24.9	21.9
Cure Rate Index	6.5	7.8	7.3	5.6	4.9	4.7

Cure 30 Min. @ 340°F:

Ring Tensile Data. Post Cure 4 hrs. @ 350°F (0 indicates no post cure.)

	0	X	0	X	0	X	0	X	0	X	0	X
Tensile Str. (psi)	1566	1797	1813	1742	1390	1813	1210	1102	1124	1085	962	974
50% Modulus	149	221	139	144	141	148	676	603	526	570	467	495
100% Modulus	450	644	369	346	364	375	1209	1070	1007	1054	868	926
200% Modulus	1461	-	1305	1128	1200	1109	-	-	-	-	-	-
Elongation	202	189	239	257	219	272	103	105	122	109	122	114
Shore A	60	55	55	55	55	55	75	70	70	70	75	65

Diffusion Rate fl. oz/sq. ft. 24 hrs.	0.37	0.33	0.32
Wt. oz/sq. yd. Coated Fabric	42	41	44

TABLE 7. PNF-200 FORMULATIONS

R-Number 211 PNF-200:	-901	-904	-906	-911	-920(904)	-922(901)
K19736	100	100	100	100	100	100
Tullanox 500	15	-	-	7	-	15
Burgess KE	-	15	-	-	15	-
Nulok 321SP	-	-	15	-	-	-
FEF	-	-	-	8	-	-
Zeolex 23	5	5	5	5	5	5
Elastomag 170	6	6	6	6	6	6
Stabilizer	2	2	2	2	2	2
Silane A151	2	2	2	2	-	-
Silane A174	-	-	-	-	2.5	2.5
Vulcup 40KE	0.4	0.4	0.4	0.4	0.4	0.4
Cure 30 Min. @ 340°F						
Tensile Str.	681	1036	968	1322	1189	1616
50% Modulus	-	-	94	108	111	175
100% Modulus	341	311	343	374	473	564
200% Modulus	-	-	891	1203	-	1478
Elongation, %	160	176	196	210	135	217
Shore A	50	40	45	50	40	60
Specific Grav.	1.8	1.8	1.9	1.9	2.0	1.8
G, psi @ 23°C	34.3	37.8	42.4	64		
T_2 °C	-45.9	-32.8	-39.5	-34.3		
T_5, °C	-52.9	-42.1	-46	-40.8		
T_{10}, °C	-58.5	-47.0	-48	-47.6		
T_{100}, °C	-67.1	-60.1	-55	-55		
Diffusion Rate fl.oz./sq.ft. - 24 hrs.				0.18		
72 hour R.T. Type II Fuel Immersion:						
W % Gain	9.7	9.7	8.0	1.4	0	1.4
V % Gain	29.1	38.5	5.6	8.3	9.5	6.8

TABLE 8. PNF-LT FORMULATIONS

R-Number 211	-902	-903	-905	-909	-918 (903)	-921 (905)	-923 (902)
PNF-LT:							
K17356	100	100	100	100	100	100	100
Tullanox 500	-	15	-	7	15	-	-
Burgess KE	15	-	-	-	-	-	15
Nulox 321SP	-	-	15	-	-	15	-
FEF	-	-	-	8	-	-	-
Zeolex 23	5	5	5	5	5	5	5
Elastomag 170	6	6	6	6	6	6	6
Stabilizer	2	2	2	2	2	2	2
Silane A151	2	2	2	2	-	-	-
Silane A174	-				2.5		
Vulcup 40KE	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Cure 30 min @ 340°F							
Tensile Strength	1488	679	802	1002	867	662	709
50% Modulus	-		-	102	230	90	80
100% Modulus	337	331	342	344	604	367	336
200% Modulus	1282	-	-	974	-	-	-
Elongation, %	213	155	163	204	134	140	147
Shore A	45	45	45	50	60	50	40
Specific Gravity	1.8	1.9	2.0	1.9	1.7	1.8	1.8
G, psi @ 23°C	85.6	33.9	38.8	65.8			
T_2, °C	-28.6	-45.3	-42.4	-44.9			
T_5, °C	-42.7	-57.0	-56.5	-53.9			
T_{10}, °C	-48.2	-60.2	-60.9	-55.4			
T_{100}, °C	-59.4	-67.0	-69.8	-65.2			
Diffusion Rate fl.oz./sq.ft. - 24 hrs.				0.38	0.74		0.46
72 hrs. R.T. Type II Fuel Immersion:							
W % Gain	7.5	13.2	0	12.2	13.2	9.9	8.8
V % Gain	12.9	33.8	17.4	32.8	33.8	32.9	29.1

TABLE 9. PNF-200 FORMULATIONS WITH INCREASING NON-REINFORCING FILLER LOADING

R-Number 211	-912	-913	-914
PNF-200 K19736	100	100	100
Nulok 321SP	20	20	20
Min-U-Sil	10	20	30
Zeolex 23-A1100	10	10	10
Elastomag 170	6	6	6
Stabilizer	2	2	2
Silane A174	2	2	2
Vulcup 40KE	0.4	0.4	0.4
Cure 30 min. at 340°F			
Tensile Strength, psi	1250	1458	1482
50% Modulus, psi	167	109	221
100% Modulus, psi	734	548	970
Elongation, %	138	167	131
Shore A	55	60	60
Specific Gravity	2.0	2.0	2.0
Diffusion Rate fl.oz./sq.ft. - 24 hrs.		0.13	0.11
72 hours R.T. Type II Fuel Immersion:			
W % gain	1.3	1.3	0
V % gain	2.8	6.4	5.1

TABLE 10. PNF-LT/ PNF-200 BLENDS

R-Number 211	-915	-916	-917
PNF-200 K19736	66.6	66.6	66.6
PNF-LT K18356	33.4	33.4	33.4
Nulok 321SP	15	-	-
Burgess KE	-	15	-
Tullanox 500	-	-	15
Zeolex 23	10	10	10
Elastomag	6	6	6
Stabilizer	2	2	2
Silane A174	2	2	2
Vulcup 40KE	0.4	0.4	0.4
Cure 30 min. @ 340°F			
Tensile Strength	879	882	1274
50% Modulus	148	122	277
100% Modulus	510	489	687
Elongation values	149	152	163
Shore A	55	55	65
Specific Gravity	1.9	1.9	1.9
Diffusion Rate fl. oz/sq. ft.- 24 hr.	0.27	0.23	0.23
72 hours R.T. Type II Fuel Immersion:			
W % gain	1.3	0.7	1.4
V % gain	11.6	15.5	10.7

TABLE 11. PNF-200 FORMULATIONS WITH HIGH FILLER LOADINGS

R-Number 211	-924	-925	-926	-927	-928	-929
PNF-200 K19736	100	100	100	100	100	100
Burgess KE	60	45	30	-	-	-
Mistron Vapor	-	-	-	60	45	30
Zeolex 23-A1100	10	10	10	10	10	10
Stabilizer	2	2	2	2	2	2
Elastomag 170	8	8	8	8	8	8
Vulcup 40KE	0.5	0.5	0.5	0.5	0.5	0.5
Cure 30 min. @ 340°F						
Tensile Strength	1464	1163	1179	1224	1410	1405
50% Modulus	467	125	155	650	568	400
100% Modulus	1362	663	654	1219	1267	1013
200% Modulus	-	-	-	-	-	-
Elongation, %	110	150	168	102	118	153
Shore A	65	60	55	70	65	65
Specific Gravity	1.9	1.8	1.9	1.9	1.9	1.7
Diffusion rate fl. oz/sq. ft.- 24 hours.	0.09	0.18	0.19	0.14	0.16	0.24
72 hours R.T. Type II Fuel Immersion:						
W % gain	17.8	18.2	13.5	13.5	13.0	20.7
V % gain	14.4	7.06	27.6	6.9	12.9	14.5

TABLE 12. HIGH CLAY AND TALC LOADING OF PNF-LT AND PNF-200

R-Number 211-	-936	-937	-938	-939	-940	-941
PNF-200 K19736	100	-	100	100	-	-
PNF-LT K18356	-	100	-	-	100	100
Burgess KE	70	70	60	80	60	80
Mistron Vapor	15	15	10	10	10	10
Zeolex 23-A1100	10	10	10	10	10	10
Stabilizer	2	2	2	2	2	2
Elastomag 170	8	8	8	8	8	8
Vulcup 40KE	0.5	0.5	0.5	0.5	0.5	0.5
Cure 30 Min. 340°F						
Tensile strength	1213	867	1407	1251	828	810
50% Modulus	712	873	664	756	639	710
100% Modulus	1203	-	1323	-	-	-
Elongation	102	55	107	86	70	65
Shore A	75	-	70	75	-	-
Specific Gravity	1.9	1.8	1.8	1.9	1.7	1.8
Diffusion Rate fl.oz/sq.ft.-24 hrs	0.07,0.10		.084,0.10	0.075,0.09		
Fabric Wt.	83, 54		78, 55	78, 56		
72 hours R.T. Type II Fuel Immersion:						
Wt. % gain	11.5	17.3	13.0	13.5	21.7	25
Vol. % gain	7.8	20.5	10.3	5.7	14.7	21.4

TABLE 13. FUEL DIFFUSION RATE OF COATED FABRICS - PNF-LT AND PNF-LT/200 BLENDS

Test Fuel: TT-S-735 Type II
(60V Iso-octane, 5V Benzene 20V Toluene, 15V Xylenes)

	Fuel Diffusion Rate	Coated Fabric Weight	Tensile Strength MPa(psi)	Elongation %
Specification	0.05 fl. oz/sq.ft. -24 hrs.	40-48 oz./ sq/yd.	10.3 (1500)	200%
PNF-LT				
R211,909	0.38	39.0	6.91 (1002)	204
R211,918	0.74*	45.9	5.98 (867)	134
R211,923	0.46	44.1	4.89 (709)	147
PNF-LT/PNF-200				
R211,910	0.21	37.5	7.90 (1146)	211
R211,919	0.30	41.7	6.77 (982)	168
PNF-LT/2 PNF-200				
R211,915	0.27	34.9	6.06 (879)	149
R211,916	0.23	40.5	6.08 (882)	152
R211,917	0.23	39.2	8.78 (1274)	168

* Diffusion sample had a flaw on interior surface. Diffusion rate may not be representative.

TABLE 14. FUEL DIFFUSION RATE OF COATED FABRICS OF PNF-200

Test Fuel: TTS-735 Type II
(60V Iso-octane, 5V Benzene, 20V Toluene, 15V Xylene)

		Fuel Diffusion Rate	Coated Fabric Weight	Vulcanizate Tensile Strength MPa (psi)	Vulcanizate Elongation %
Specification:		0.05 fl. oz/sq.ft. -24 hrs.	40-48 oz./ sq.yd.	10.3 (1500)	200%
PNF-200					
R211,911		0.18	40.7	9.11 (1322)	210
R211,913		0.13	45.1	9.25 (1342)	142
R211,914		0.11	38.9	9.65 (1399)	122
R211,920		0.145	42.3	8.20 (1189)	135
R211,922		0.073	37.3	11.1 (1616)	217
R211,924	A.	0.09	56.5	10.1 (1464)	110
	B.	0.08	46.8		
R211,924R	A.	0.096	64	10.1 (1464)	110
	B.	0.10	54		
R211,925		0.18	48	8.02 (1163)	150
R211,926		0.19	45	8.13 (1179)	168
R211,924		0.02 (Arctic Diesel Fuel)			

TABLE 15. FUEL DIFFUSION RATE OF COATED FABRICS

Test Fuel: TTS-735 Type II
(60V Iso-octane, 5V Benzene, 20V Toluene, 15V Xylene)

		Fuel Diffusion Rate	Coated Fabric Weight	Vulcanizate Tensile Strength MPa (psi)	Vulcanizate Elongation %
Specification:		0.05 fl. oz/sq.ft. - 24 hrs.	40-48 oz./ sq.yd.	10.3 (1500)	200%
R211,927		0.14	48	8.44 (1224)	98
R211,928		0.16	42	8.26 (1198)	101
R211,929		0.24	34	9.46 (1373)	144
R211,936	A.	0.07	83	8.36 (1213)	102
	B.	0.10	54		
R211,938	A.	0.084	78	9.70 (1407)	107
	B.	0.10	55		
R211,939	A.	0.075	78	8.19 (1189)	86
	B.	0.09	56		
R211,94		0.17	42	6.02 (874)	183

TABLE 16. DIFFUSION TEST FUEL SAMPLE ANALYSIS

COMPONENT WEIGHT PER CENT LOSSES OVER TEST DURATION

Test Fuel: TT-S-735 Type II

PNF-LT	Diffusion Rate fl.oz/sq.ft. (24 hrs)	Coated Fabric oz./sq. yd.	Test Duration Days	Iso-Octane	Benzene	Toluene	Xylenes
R211,909	0.38	39	23	7.6	41	26.9	17.7
R211,918*	0.74	45.9	38	50.2	95	90.4	78.1
R211,923	0.46	44.1	28	10.2	66.3	46.5	31.1
PNF-LT/PNF-200 BLEND							
R211,910	0.21	37.6	39	2.4	49	31.4	21.9
PNF-LT/2 PNF-200 BLEND							
R211,916	0.23	40.5	39	1.8	55	36.4	23.8
R211,917	0.23	39.2	23	8.4	35.5	18.4	12.0

*Sample had a flaw on interior surface coating after removal from diffusion test cup. Diffusion result may not be representative.

TABLE 17. DIFFUSION TEST FUEL SAMPLE ANALYSIS

COMPONENT WEIGHT PER CENT LOSSES OVER TEST DURATION

Test Fuel: TT-S-735 Type II

PNF-200	Diffusion Rate fl.oz./ sq.ft. (25 hrs)	Coated Fabric oz/sq. yd.	Test Duration Days	Iso-Octane	Benzene	Toluene	Xylenes
R211,913	0.13	45.1	23 days	0	17.0	9.1	6.1
R211,914	0.11	38.9	23	3.8	18.9	13.3	11.1
R211,920	0.15	42.3	38	1.3	40.0	21.2	8.9
R211,922	0.07	37.8	28	0	15.	7.1	12.2
R211,924 A.	0.09	56.5	38	0.6	19.3	12.4	5.8
R211,924 B.	0.08	46.8	28	0	16.1	8.5	7.5

TABLE 18. LOW TEMPERATURE FLEXIBILITY PNF® COATED FABRIC*

R-Number 211,	913	914	917	920	922	924
Room Temp. G, psi	713	740	1027	1018	1275	593
7 days @ -40°F						
TSR	2.9	2.5	3.0	2.0	2.3	2.2
G, psi	2100	1860	3040	2040	2910	1300
7 days at -70°F						
TSR	9.7	9.3	6.4	4.5	6.6	19.8
G, psi	6900	6860	6570	4550	8440	11730
Fuel Diffusion Rate Fl. oz/ft^2-24 hrs.	0.13	0.11	0.23	0.15	0.073	0.08
Oz/ Yd^2	45.1	38.9	39.2	42.3	37.3	46.8
			VULCANIZATE PROPERTIES:			
Tensile Strength	1458	1482	1274	1189	1616	1464
Elongation	167	131	168	135	217	110
			FORMULATION			
PNF-200	100	100	66.6	100	100	100
PNF-LT	--	--	33.4	--	--	--
Burgess KE	--	--	--	15	--	60
Nulok 321 SP	20	20	--	--	--	--
Min-U-Sil	20	30	--	--	--	--
Tullanox 500	--	--	15	--	15	--
Zeolex 23-A1100	10	10	10	5	5	10
Elastomag 170	6	6	6	6	6	8
Stabilizer	2	2	2	2	2	2
Silane A174	2	2	2	2.5	2.5	--
Vulcup 40 KE	0.4	0.4	0.4	0.4	0.4	0.5

*Low temperature flexibility measurements obtained by P. Touchet, MERDC .

TABLE 19. PNF-200 PROCESSING STUDY-SILICONE ADDITIONS

R-Number 211-	-950	-951	-952	-953	-954	-955
PNF-200 K19736	100	100	100	100	100	100
HA-2	2	2	2	4	4	4
Tullanox 500	20	10	10	20	10	10
Burgess KE	-	10	10	-	10	10
Mistron Vapor	-	5	10	-	5	10
Min-U-Sil	10	10	10	10	10	10
Zeolex 23 A1100	5	5	5	5	5	5
Elastomag 170	8	8	8	8	8	8
Silane A174	2.5	2.5	2.5	2.5	2.5	2.5
Vulcup 40KE	0.4	0.4	0.4	0.4	0.4	0.4
Cure 30 min. 340°F Post Cure 4 hours @ 350°F						
Tensile Strength	1605	1101	1115	1054	1104	1231
50% Modulus	226	144	186	234	176	258
100% Modulus	558	578	636	594	595	820
200% Modulus	1424	-	-	-	-	-
Elongation, %	222	153	155	151	157	145
Shore A	65	60	60	65	60	65
Mill Processability: Ability to release from mill roll as thin (.015") sheet.	Fair	Good	Good	Poor	Fair	Fair
Diffusion Rate "Fuel S" fl oz/sq ft. - 24 hrs.			0.25			0.29
Coated Fabric weight oz/sq. yd.			45			50

TABLE 20. PNF-200 PROCESSING STUDY-FLUOROSILICONE ADDITIONS

R-Number 211	-956	-957	-958	-959	-960	-961
PNF-200 K19736	100	100	100	100	100	100
FSE2620U	2	2	2	4	4	4
Tullanox 500	20	10	10	20	10	10
Burgess KE	-	10	10	-	10	10
Mistron Vapor	-	5	10	-	5	10
Min-U-Sil	10	10	10	10	10	10
Zeole 23 A1100	5	5	5	5	5	5
Elastomag 170	8	8	8	8	8	8
Silane A174	2.5	2.5	2.5	2.5	2.5	2.5
Vulcup 40KE	0.4	0.4	0.4	0.4	0.4	0.4
Cure 30 Min. 340°F Post Cure 4 hours @ 350°F						
Tensile Strength	1314	1173	1150	733	974	1155
50% Modulus	202	209	265	242	173	262
100% Modulus	499	733	809	578	573	793
200% Modulus	1195	-	-	-	-	-
Elongation, %	221	142	134	122	144	137
Shore A	60	60	60	60	50	60
Mill Processability: Ability to release from mill roll as thin (.015" sheet).	Fair	Good	Good	Fair	Good	Poor
Diffusion Rate "Fuel δ " fl. oz/sq. ft. - 24 hrs.			.20			.23
Coated Fabric, Weight oz/sq. yd.			48			43

TABLE 21. PNF-200 PROCESSING STUDY - THERMALLY AGED POLYMER

R-Number 211, Polymer DSV (dl/g) PNF-200	962 2.14 K19861	963 2.22 K19861A4*	964 2.12 K19861A6	965 2.06 K19861A8	966 2.06 K19861A10	967 2.03 K19861A12
Tullanox 500	20					
Min-U-Sil	10					
HA-2	2					
Zeolex 23-A1100	5					
Elastomag 170	8					
Silane A174	2.5					
		Same as -950 Except Silane added to mix				
Vulcup 40KE	0.4					
f = 0.65	Mix to 30,000 M-gm-min total integrated torque					
Polymer Torque	600	600	600	500	500	500
Peak Torque	3200	3450	3400	2000	3600	3650
Plateau Torque	1000	1400	1400	1200	1270	1330
Max. Temp. °C	73°	82°	79°	84°	92°	88°
Tensile Strength	1100	1010	1134	1033	1238	1158
50% Modulus	260	215	241	232	294	259
100% Modulus	543	481	492	487	599	508
200% Modulus	--	--	1131	--	--	1090
Elongation, %	182	177	202	186	187	211
Shore A	65	65	65	65	65	65
Fuel Diffusion Rate $\frac{\text{fl. oz.}}{\text{sq. ft.}}$ - 24 hrs.	0.30	0.32		0.31		0.27
Coated Fabric Weight oz/sq. yd.	45	48		46		45

*"A4" indicates polymer aged 4 hours in air at 300°F.

TABLE 22. PNF-200 THERMALLY AGED POLYMER PROCESSING STUDY

R-Number: 211,	968	969	970	971	972	973
Polymer DSV (dl/g)	2.14	2.05	1.86	2.57	2.45	2.49
PNF-200	K19862	K19862A4*	K19862A8	K19736	K19736A4	K19736
Tullanox 500	20					
Min-U-Sil	10					
HA-2	2					
Zeolex 23-A1100	5					
Elastomag 170	8					
Silane A174	2.5					
Vulcup 40KE	0.4					
f=0.65						
Polymer Torque	580	600	600	750	750	600
Peak Torque	3800	3550	4200	3500	3600	3700
Plateau Torque	1580	1500	1650	1646	1638	1600
Max. Temp. °C	89	98	84	92	100	98
Integrated Torque	20,000	Meter gram minutes				
Tensile Strength	1120	1276	1333	1255	1098	1251
50% Modulus	246	241	324	316	350	387
100% Modulus	522	536	636	616	661	725
200% Modulus	--	1185	--	--	--	--
Elongation %	172	216	198	199	167	158
Shore A	65	60	70	70	70	70
Diffusion Rate - Fuel δ fl. oz./sq. ft.-24				0.28	0.27	0.33
Coated Fabric Weight oz./sq. yd.				51	54	51

*"A4" indicates polymer aged 4 hrs. in air @ 300°F.

TABLE 23. PNF-200 THERMALLY AGED POLYMER PROCESSING STUDY

R-Number 211,	976	977	978	979	980	981
PNF-200	K19861	K19861A4*	K19861A6	K19861A8	K19861A10	K19861A12
Tullenox 500	20					
Min-U-Sil	10					
Zeolex 23-A11CO	5					
Elastomag 170	8					
Silane A174	2.5					
Vulcup 40KE	0.4					
f= .65						
Tensile Str	1408	1536	1552	1552	1408	1439
50% Mod	202	200	212	290	294	204
100% Mod	530	555	611	719	711	596
200% Mod	1405	1420	1563	1556	--	--
Elongation %	210	217	199	200	184	193
Shore A	60	60	60	65	65	60
Specific Gravity	1.95	1.92	1.92	1.92	1.96	1.92

*"A4" indicates polymer aged 4 hrs. @ 300°F.

TABLE 24. PNF-200 THERMALLY AGED POLYMER PROCESSING STUDY

R-Number 211,	982	983	984	985	986	987
PNF-200	K19862	K19862A4*	K19862A8	K19736	K19736A4	K19736A8
Tullanox 500	20					
Min-U-Sil	10					
Zeolex 23-A (Na)	5					
Elastomag 170	3					
Silane A174	2.5					
Vulcup 40KE	0.4					
Tensile Strength	1528	1520	1496	1555	1378	1527
50% Mod	195	221	236	321	307	325
100% Mod	570	636	655	857	750	834
200% Mod	--	--	1485	--	--	--
Elongation %	197	191	192	171	176	169
Shore A	60	60	60	65	65	65
Specific Gravity	1.97	1.92	1.92	1.94	1.88	1.90

*A4" indicates polymer aged 4 hrs. @ 300°F.

TABLE 25 BANBURY "BR" MIXES and COAGENT ADDITION

R-Number	211988	211992	211993	211994
PNF-200	K19730	K19730	K19730	K19730
Burgess KE	60	60	60	60
Zeolex 23-A1100	10	10	10	10
Elastomag 170	8	8	8	8
Stabilizer	2	--	--	2
Silane A1100	--	2.5	2.5	--
TAIC	--	--	1.5	1.5
Vulcup 40KE	0.5	0.5	0.5	0.5
f-	12.22 4 batches	12.22 5 batches	1	1

Cure 30 Min. 150°C
Post Cured 4 hrs. at 175°C (O indicates no post cure)

	O	X	O	X	X	X
Tensile Str.	1377	1378	1473	1330	1125	1414
50% Mod	417	355	424	389	506	396
100% Mod	1160	1015	1223	1150	--	1217
Elongation	120	142	127	118	99	117
Shore A	65	65	65	65	65	65
Tear Strength Die C lbs./ga. (load/gage)		86		58		

TABLE 26. WEATHER-O-METER AGING

PNF 200 COMPOUNDS

TEST CONDITIONS: CAM NO. 47 18 HOURS 102 MIN. LIGHT, 18 MIN., WATE
6 HOURS DARK, NO WATER

Unaged Properties:

	R211 [illegible]		R211 [illegible]22	
Tensile Strength	1377		1630	
50% Modulus	355		389	
100% Modulus	1015		1150	
% Elongation	141		118	
Shore A	65		65	
206 Hours (Total Light):				
		% Change		% Change
Tensile Strength	1134	(-17%)	1105	(-16.9%)
50% Modulus	339	(-4.5%)	306	(-21%)
100% Modulus	936	(-7.8%)	92[illegible]	(-19.2%)
% Elongation	125	(-11.6%)	123	(+4.2%)
Shore A	65		65	
500 Hours (Total Light):				
Tensile Strength	1168	(-15%)	1073	(-19.3%)
50% Modulus	387	(-9%)	366	(-5.9%)
100% Modulus	980	(-5%)	987	(-14%)
% Elongation	127	(-10%)	112	(-5%)
Shore A	65	0	65	0

TABLE 27. "FUEL 6" AGING OF MICRO-TENSILE RINGS

R211988

Aging of Rings at 160°F in Fuel "6"

	Original Properties	Aged 14 Days	% Change	28 Days	% Change	42 Days	% Chang
Tensile	1378	1092	(-20.8)	1054	(-23.5)	1043	(-24.3
50% Mod	355	177	(-50.1)	137	(-6)	166	(-53.2
100% Mod	1015	749	(-26.2)	667	(-34.3)	684	(-32.6
Elongation %	142	143.5	(+1.0)	145.1	(+2)	143	(+7)
Shore A	65	55		55		55	

TABLE 28. FUEL CONTAMINATION TESTS

Procedure: Para 4.6.2.1.1 and .2 of MIL T-52573C ASTM D381

	MIL-T-52573	DESIRED VALUE DAAG46-73-0006	R211988 TEST FUEL S Mg/100ml	R21199 FUEL S Mg/100ml
Unwashed Existent gum Mg/100ml, max.	60	20	4.0	1.0
Heptane washed existent gum Mg/100ml, max.	--	5	2.0	0.6
Stoved gum, residue Mg/100ml, max.	20	--	0.6	-0-

TABLE 29. FUEL DIFFUSION RATE COATED FABRIC AND VULCANIZATES

Test Fuel: Fuel δ (60v iso octane, 25v toluene, 15v xylenes)

Stock	Fuel δ Diffusion Rate	Coated Fabric Weight	Vulcanizate Weight	Thickness Mils	Remarks
	fl.-oz./sq. ft.-24 hrs.	oz./yd.^{2}	oz./yd.^{2}		
211988	0.21	--	42.4	29.	wrap cured in oven 30' 350°F, 4 hrs. 350°
211988	0.09	--	93.6	60	
211994	0.12	--	71.0	51	TAIC Coagent in 211988
211993	0.10	--	71.6	51	TAIC Coagent in 211992
211992	0.095	--	83.1	55	1508-37 wrap cured
					fabric treatment:
211992	0.036	89.2	--	66	TX-9 Thixon 300/301
211992	0.023	92.0	--	68	TX-10 Thixon 300/301 on PNF-200 dispersion
211974	<0.01	78.5	--	59	purified polymer: TX-11 Thixon 300/301
211975	<0.01	70.0	--	52	TX-12 Thixon 300/301
211992	0.041	98.1	--	72	TX-13 3.4% T.S. Thixon 300/301 Nylon Backing
211992	0.042	94.8	--	67	TX-14 3.4% T.S. Thixon 300/301
211992	0.05	78.8	--	58	TX-15A 3.4% T.S. Thixo 300/301
WO-05504 Type II Fuel	0.096	33.9	--	47	Coated Fabric Reported to meet Mil T-525730 Fuel Diffusion Requirements
	0.107	33.7	--	47	
WO-03305 Type II	0.037	34.1	--	44	
	0.050	34.1	--	44	

TABLE 30. FUEL DIFFUSION TESTS OF COATED FABRICS WITH VARIOUS FABRIC SURFACE TREATMENTS

Stock	Fuel Diffusion Rate fl./oz/sq. ft.- 24 hrs.	Coated Fabric Weight oz/yd^2	Thickness Mils	Remarks
211992	0.052	60.9	45	Thixon A/B
211992	0.10	58.0	45	Chemlok AP134
211992	0.10	59.6	45	Chemlok 607
211992	0.096	60.6	45	Fluorel FC5150

TABLE 31. BREAKING STRENGTH OF COATED FABRICS WITH VARIOUS FABRIC SURFACE TREATMENTS

Stock: 211992

Initial lbs/in	thickness	Aged at 160°F 8 Days - Water lbs/in	thickness initial	thickness final	Aged at 160°F 8 Days in Fuel B lbs/in	thickness initial	thickness final	Fabric Surface Treatment
1B 311	43 mils	300	47	57	239	45	45	
350		300		56	239		46	
340								
Average 334		300 (-10%)			239 (-28%)			Thixon 300/30
2B 175	44	214	46	57	160	44	45	
171		212	46	57	161		44	
180								Chemlok AP 134
Average 175		213 (+22%)			160 (-8%)			
3B 282	44	310	46	61	217	42	45	
282		285	46	60	185		44	
255								
Average 273		298 (+9%)			201 (-26%)			Chemlok 607
4B 371	44	275	45	57	286	43	45	
373		283	45	59	261		45	
380								
Average 375		279 (-26%)			273 (-27%)			Fluorel FC5150

TABLE 32. REPEAT MIXES AND MIXER FILLING FACTOR CHECK

R-Number 211,	995 (944)	996 (945)	997 (946)	998	999
PNF-200	19736	K19861	K19862	K19736	K19736
Tullanox 500	15	→	→	→	→
Zeolex 23 A1100	5	→	→	→	→
Elastomag 170	6	→	→	→	→
Stabilizer	2	→	→	→	→
Silane A174	2.5	→	→	→	→
Vulcup 40KE	0.4	→	→	→	→
filling factor f=	0.6	0.6	0.6	1	0.8
Torque	20,000 M-gm-min				
Max Temp.	85°C	81°C	75°C	97°C	90°C
Cure 30 min at 150°C					
Post cure 4 hours at 176°C					
Tensile Strength	1439	1711	1985	1957	1911
50% Modulus	164	107	141	183	174
100% Modulus	384	294	394	533	461
200% Modulus	1114	1094	1410	1640	1392
Elongation %	233	251	246	226	246
Shore A	55	50	55	55	55
Specific Gravity	1.9	1.9	1.9	1.9	1.9
	R211944	R211945	R211946		
Tensile Strength	1797	1742	1813		
50% Modulus	221	144	148		
100% Modulus	644	346	375		
200% Modulus	--	1128	1109		
Elongation %	189	257	272		
Shore A	55	55	55		
f=1					

TABLE 33. ADHESIVE PEEL STRENGTH TESTS OF PNF®-200 COATED FABRIC

2x2 NYLON BASKET WEAVE 8.5 oz/yd^2

Stock	Fabric Surface Treatment	Coated Fabric Thickness	180° Peel Strength	
211988	PNF-200 211992 dispersion +0.25 Vulcup 40KE + 0.25 TAIC	68	A-1	1.0 ppi
		69	A-2	1.05
		72	A-3	1.05
		72	A-4	1.1
211992	AS ABOVE	70	A-5	2.04
		74	A-6	2.33
		69	A-7	2.00
		72	A-8	1.9
		68	A-9	1.48
211988	Thixon A/B	68	TS-88A	8.7
			TS-88B	7.6
211988	Nylon 8061 + 211992 dispersion	68	N-1A	1.0
		68	N-1B	1.0
	Nylon 8064 + 211992 dispersion	70	N-2A	1.0
		70	N-2B	0.9
211992	Resorcinol-formaldehyde - Vinyl pyridine latex FRS-262 Ammonium hydroxide	77	AR-1A	1.0
			AR-1B	0.9
211988	Resorcinol-formaldehyde vinyl pyridine latex FRS-262 Sodium hydroxide C-103 Fabric	55	R-1A	3.0
			R-1B	2.5
211988	Thixon A/B 1:10 dilution	71	TX-3A	1.5
			TX-3B	1.8
	Thixon A/B 1:100 dilution	66	TX-4A	0.9
			TX-4B	0.9
	Chemlok 607/Z6020	65	CH-1A	1.1
			CH-1B	1.0

TABLE 34. ADHESIVE PEEL STRENGTH TESTS OF PNF©-200 COATED FABRIC

2x2 NYLON BASKET WEAVE

Stock	Fabric Surface Treatment	Coated Fabric Thickness	180° Peel Strength	
211988	Thixon A/B No post cure	68	988-S-A	7.3
			988-S-B	6.3
			TS-88A	9.5
			TS-88B	8.8
211992	Thixon A/B	68	TS-92A	4.4+
			TS-92B	4.2
211992	Thixon A/B 1:10 dilution	60	TX-1A	2.1
			TX-1B	2.1
	Thixon A/B 1:10 dilution	55	TX-2A	4.7
			TX-2B	5.1
211992	Chemlok AP133	65	CH133-1	3.2
	Chemlok AP133 1:1 methanol dilution		CH133-2	3.6
	Chemlok AP133 2 hr. air dry			2.3
	Thixon A/B + PNF-200 165°C 30 min. Nylon C103 backing 4 hr. post cure 350°F	67	TX-9	7.8
		68	TX-10	5.5

Table [illegible]. ADHESIVE PEEL STRENGTH AND BREAKING STRENGTH OF COATED FABRIC

Stock	Thickness Mils	Breaking Strength	180° Peel Strength	Remarks	Fabric Surface Treatment
211922	67	370 lbs/in	6.3 ppi	TX5A	Thixon 30 min 150°C press cure
	66	350	5.95		
	72	420	4.5	TX6A	Thixon 30 min 160°C press cure
	71	407	4.5	TX6B	
	70	420	5.7	TX7A	Thixon 30 min 170°C press cure
	70	375	5.95	TX7B	
	65	280	5.5	TX8A	Thixon 30 min 150°C press cure
	66	280	5.5	TX8B	+Zonyl FSN

TABLE [illegible]. STABILIZER MASTERBATCH FORMULATION

		219600	219606
PEF-200	K19736	67.2	--
	K19862	32.8	100
Burgess KE		20	20
Zn II bis(quinolate)		40	40
[illegible]		3.29	3.29
[illegible]		1	2

[illegible] = Zn II bis(quinolate) ball milled to reduce particle size of stabilizer.

TABLE 57. BANBURY "BR" MIXES OF PNF®-200

R-Number	219601	219602	219607	219608	219609
PNF-200	K19736	K19862	K19861	K19861	1508-49
Burgess KE	55	55	--	60	60
Tullanox 500	--	--	15	--	--
Zeolex 23-A1100	8	8	5	10	10
Elastomag 170	8	8	6	8	8
Silane A1100	1	1	1.5	1.5	1.5
Stabilizer as					
R219600	8	8	--	--	--
R219606	--	--	4	4	4
Vulcup 40KE	0.4	0.4	0.4	0.5	0.5
No. of Batches	3	2	4	5	3
loading factor f=	12.59	12.59	16.68	11.96	11.96
Max Temp. during mix	172°F	172°F	152°F	165°F	165°F
	Batches Combined Labeled 219601				
Monsanto Rheometer Data	T=340°F, 1° Arc 100 RPM, Mini die				
Scorch Time	4.2		4.7	3.7	3.5
Opt cure TC(90)	17.5		14.0	20.0	20.0
Min Torque	9.9		6.5	10.3	10.1
Torque at 90% cure	15.7		10.5	17.0	17.2
Max Torque	16.3		10.9	17.7	18.0
Cure Rate Index	7.5		10.8	6.1	6.1
Cure 30 min at 340°F 4 hrs at 350°F					
Ring Tensile Data					
Tensile Strength	1392		1562	1303	1309
50% Modulus	241		71	286	292
100% Modulus	849		211	872	917
200% Modulus	--		797	--	--
Elongation	157		294	158	140
Shore A	60		45	65	65
Specific Gravity	2.1		1.9	2.1	2.1

TABLE 38. COMPARISON OF PHYSICAL PROPERTIES OF VULCANIZATES WITH PURIFIED POLYMER 1508-28

	R211974	R211975	R219603	R211924
PNF-200	1508-28	1508-28	1508-28	K19736
Burgess KE	60	60	60	60
Zeolex 23-A1100	10	10	10	10
Elastomag 170	8	8	8	8
Stabilizer	2	--	--	2
R211855		4	--	
Vulcup 40KE	0.5	0.5	0.5	.5
Cure 30' 150°C 4 hrs. 176°C				
Tensile Strength	1482	1499	1185	1464
50% Mod	464	425	354	467
100% Mod	1371	1316	1141	1362
200% Mod	--	--	--	--
Elongation %	109	112	107	110
Shore A	65	65		65
Specific Gravity		2.1		
Diffusion Rate Fuel S	0.1	0.1	0.052	0.087* 0.09
Coated Fabric Weight	78.5	70	60	78* 56.5

A 14 wt.% PNF-200, K19801, polymer solution (methanol), filtered, coagulated in water, and vacuum dried (1508-28).

	K19861	1508-28
DSV (dl/g)	2.3	2.3
gel (%)	0.0	0.0
Na (wt.%)	0.014	0.0
Cl (wt.%)	0.022	0.0

*Vulcanizate wt. oz/yd^2

TABLE 39. COMPARISON OF PHYSICAL PROPERTIES OF K19861 VS PURIFIED POLYMER (1508-49)

Stock	219608		219609	
Original:				
Tensile Strength	1303		1309	
50% Modulus	286		292	
100% Modulus	872		917	
Elongation at Break	158		140	
Shore A	65		65	
Aged: Fuel C 3 Days at 160°F				
Tensile Strength	1139	(-12.5%)	1145	(-12.5%)
50% Modulus	194	(-32%)	159	(-45.5%)
100% Modulus	773	(-11.4%)	765	(-16.6%)
Elongation at Break	143	(-9.5%)	136	(-2.8%)
Shore A	60	(-7.7%)	60	(-7.7%)
Aged: Fuel C 14 Days at 160°F				
Tensile Strength	1112	(-14.6%)	1192	(-8.9%)
50% Modulus	210	(-26.5%)	232	(-20.5%)
100% Modulus	807	(-7.5%)	884	(-3.5%)
Elongation at Break	135	(-14.6%)	132	(-2.8%)
Shore A	60	(-7.7%)	60	(-7.7%)

TABLE 40. FUEL DIFFUSION TESTS - VULCANIZATES AND COATED FABRICS

Stock	Fuel Diffusion Rate Fl. oz/sq ft-24 hrs	Coated Fabric oz/sq. yd	Vulcanizate Weight oz/sq. yd	Thickness Mils	Fabric Surface Treatment
219501	0.09	--	90	50	
219601	0.07	64	--	48	A-Thixon 300/301 3.8% T.
219601	0.12	57	--	45	B-Fluorel 5150
219607	0.19	--	87	64	
219607	0.08	55	--	45	A
219607	0.18	53	--	43	B
219608	0.08	--	87	58	
219608	0.06	58	--	45	A
219608	0.09	62	--	47	B
219609	0.08	--	87	58	
219609	0.06	63	--	46	A
219609	0.10	60	--	46	B

TABLE A1. BREAKING STRENGTH OF WATER AGED COATED FABRICS

Stock	Surface Treatment	Thickness Mils	ozs/sq. yd	7 Days at 160°F in DI water Breaking Strength ppi
219601	Thixon 300/301	48	64	240
	Fluorel 5150	45	57	337
219607	Thixon	45	55	370
	Fluorel	45	53	383
219608	Thixon	45	58	288
	Fluorel	47	62	327
219609	Thixon	48	63	345
	Fluorel	46	60	340

TABLE 42. PHYSICAL PROPERTIES OF - WRAP CURED CALENDERED SHEET

Stock: R211992
Calendered Thickness: 0.055-0.053"
Calendered Width: 10"
Cured: 30 min. at 350°F
Wrapped around aluminum tube - interleaved .005" steel shim.
Check of stress-strain properties along strip every six inches.
Post Cured: Un-wrapped 4 hours 350°F oven

	1508-37-1	1508-37-2	1508-37-3	1508-37-4
Tensile Str.	1212	1257	1275	1298
50% Modulus	389	379	404	400
100% Modulus	1132	1127	1169	1196
% Elongation at Break	109	114	115	110
Shore A	60	60	60	60
Specific Gravity	2.1	2.1	2.1	2.2

Press Cured 30 min. at 350°F 4 hours at 350°F

	R211992
Tensile Str.	1130
50% Modulus	389
100% Modulus	1150
Elongation	118
Shore A	65

TABLE 43. SEAM ADHESION PEEL STRENGTH

Press Cured Adhesion Pads

Thixon Treated Fabric	Initial Strength	Fabric - To Rubber Strength	
211988 - 1	8.2 ppi		
2	9.0		
3	8.5		
4	8.7		
5	8.6		
6	7.8		
7	8.2		
Thixon Treated Fabric: Press Cured Adhesion Pads			
211988 - 2-1	--	2.7 ppi	
2-2	--	6.0	
Thixon/Fluorel 5150 Treated Fabric:			
219601 - 1	7.7 ppi	6.0	seam failure
2	8.8	6.2	" "
3	9.3	6.2	" "
Wrap Cured Seam - Fluorel Treated Thixon/Fluorel Treated Fabric			
219601 - 1	9.6 ppi		
2	9.2		
3	8.8		
4	9.2		
Press Cured Seam Calender Fabric Treated with 5% 219607 in MIBK			
Seam Treatment: Chemlok 607 Spray			
219608 - 1	10.8	6.0 ppi	
2	10.4	6.0	
3	8.0	5.0	
Seam Treatment: Acetone Wipe			
219608 - 1	12 ppi	3.0	
2	12	5.0	
3	12	5.0	

Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
PHOSPHONITRILIC FLUOROELASTOMER COATED FABRICS
FOR COLLAPSIBLE FUEL STORAGE TANKS
Richard W. Sicka and George H. Mitchell
Firestone Central Research Laboratories
1200 Firestone Parkway, Akron, OH 44317
Final Report AMMRC TR 79-44, July 1979, 65 pp illus - tables; Contract DAAG46-78-C-0006; D/A Project: 1L163102D071; AMCMS Code: 63102; Agency Accession: DA0F4788

AD ____________

UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Inorganic polymers
Polyphosphazenes
Phosphonitrilic fluoroelastomers
Coated fabrics
Fuel tanks
Storage tanks

This report describes the preparation of fuel resistant coated fabric materials that are serviceable at temperatures as low as -70°F. The coated fabric materials were made from a phosphonitrilic fluoroelastomer compound coated on nylon fabric. Efforts were directed toward attainment of calenderable compounds and test evaluations of the coated fabric. High filler loaded materials proved to be better processable materials. These showed good diffusion rates with test fluids (TT-S-735, Type II and Fuel B). Even better diffusion rates were seen with Arctic diesel fuel. The low temperature flexibility of the vulcanizates and coated fabric was promising for PNF-200 compounds. The seam adhesion strength and the fabric-to-rubber adhesion need to be improved before utilization of this material in tank constructions.

Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
PHOSPHONITRILIC FLUOROELASTOMER COATED FABRICS
FOR COLLAPSIBLE FUEL STORAGE TANKS
Richard W. Sicka and George H. Mitchell
Firestone Central Research Laboratories
1200 Firestone Parkway, Akron, OH 44317
Final Report AMMRC TR 79-44, July 1979, 65 pp illus - tables; Contract DAAG46-78-C-0006; D/A Project: 1L163102D071; AMCMS Code: 63102; Agency Accession: DA0F4788

AD ____________

UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Inorganic polymers
Polyphosphazenes
Phosphonitrilic fluoroelastomers
Coated fabrics
Fuel tanks
Storage tanks

This report describes the preparation of fuel resistant coated fabric materials that are serviceable at temperatures as low as -70°F. The coated fabric materials were made from a phosphonitrilic fluoroelastomer compound coated on nylon fabric. Efforts were directed toward attainment of calenderable compounds and test evaluations of the coated fabric. High filler loaded materials proved to be better processable materials. These showed good diffusion rates with test fluids (TT-S-735, Type II and Fuel B). Even better diffusion rates were seen with Arctic diesel fuel. The low temperature flexibility of the vulcanizates and coated fabric was promising for PNF-200 compounds. The seam adhesion strength and the fabric-to-rubber adhesion need to be improved before utilization of this material in tank constructions.

Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
PHOSPHONITRILIC FLUOROELASTOMER COATED FABRICS
FOR COLLAPSIBLE FUEL STORAGE TANKS
Richard W. Sicka and George H. Mitchell
Firestone Central Research Laboratories
1200 Firestone Parkway, Akron, OH 44317
Final Report AMMRC TR 79-44, July 1979, 65 pp illus - tables; Contract DAAG46-78-C-0006; D/A Project: 1L163102D071; AMCMS Code: 63102; Agency Accession: DA0F4788

AD ____________

UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Inorganic polymers
Polyphosphazenes
Phosphonitrilic fluoroelastomers
Coated fabrics
Fuel tanks
Storage tanks

This report describes the preparation of fuel resistant coated fabric materials that are serviceable at temperatures as low as -70°F. The coated fabric materials were made from a phosphonitrilic fluoroelastomer compound coated on nylon fabric. Efforts were directed toward attainment of calenderable compounds and test evaluations of the coated fabric. High filler loaded materials proved to be better processable materials. These showed good diffusion rates with test fluids (TT-S-735, Type II and Fuel B). Even better diffusion rates were seen with Arctic diesel fuel. The low temperature flexibility of the vulcanizates and coated fabric was promising for PNF-200 compounds. The seam adhesion strength and the fabric-to-rubber adhesion need to be improved before utilization of this material in tank constructions.

Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
PHOSPHONITRILIC FLUOROELASTOMER COATED FABRICS
FOR COLLAPSIBLE FUEL STORAGE TANKS
Richard W. Sicka and George H. Mitchell
Firestone Central Research Laboratories
1200 Firestone Parkway, Akron, OH 44317
Final Report AMMRC TR 79-44, July 1979, 65 pp illus - tables; Contract DAAG46-78-C-0006; D/A Project: 1L163102D071; AMCMS Code: 63102; Agency Accession: DA0F4788

AD ____________

UNCLASSIFIED
UNLIMITED DISTRIBUTION

Key Words

Inorganic polymers
Polyphosphazenes
Phosphonitrilic fluoroelastomers
Coated fabrics
Fuel tanks
Storage tanks

This report describes the preparation of fuel resistant coated fabric materials that are serviceable at temperatures as low as -70°F. The coated fabric materials were made from a phosphonitrilic fluoroelastomer compound coated on nylon fabric. Efforts were directed toward attainment of calenderable compounds and test evaluations of the coated fabric. High filler loaded materials proved to be better processable materials. These showed good diffusion rates with test fluids (TT-S-735, Type II and Fuel B). Even better diffusion rates were seen with Arctic diesel fuel. The low temperature flexibility of the vulcanizates and coated fabric was promising for PNF-200 compounds. The seam adhesion strength and the fabric-to-rubber adhesion need to be improved before utilization of this material in tank constructions.

DISTRIBUTION LIST

No. of Copies	To
1	Office of the Under Secretary of Defense for Research and Engineering, The Pentagon, Washington, D. C. 20301
12	Commander, Defense Documentation Center, Cameron Station, Building 5, 5010 Duke Street, Alexandria, Virginia 22314
1	Metals and Ceramics Information Center, Battelle Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201
	Office of the Deputy Chief of Staff for Research, Development, and Acquisition, Washington, D. C. 20310
2	ATTN: DAMA-ARZ
	Commander, Army Research Office, P. O. Box 12211, Research Triangle Park, North Carolina 27709
1	ATTN: Information Processing Office
	Commander, U. S. Army Materiel Development and Readiness Command, 5001 Eisenhower Avenue, Alexandria, Virginia 22333
1	ATTN: DRCLDC, Mr. R. Zentner
	Commander, U. S. Army Electronics Research and Development Command, Fort Monmouth, New Jersey 07703
1	ATTN: DRDCO-GG-DD
1	DRDCO-GG-DM
	Commander, U. S. Army Armament Research and Development Command, Dover, New Jersey 07801
2	ATTN: Technical Library
1	DRDAR-SCM, Mr. J. D. Corrie
1	DRDAR-LCA-OP, Charles C. Wright
1	Plastics Technical Evaluation Center, PLASTEC, Harry E. Pebly, Jr., Director
1	SARPA-FR-M-D, PLASTEC, A. M. Anzalone
	Commander, U. S. Army Natick Research and Development Command, Natick, Massachusetts 01760
1	ATTN: DRDNA-VMP, Angus Wilson
	Commander, U. S. Army Mobility Research and Development Command, Fort Belvoir, Virginia 22060
1	ATTN: DRDME-VU, Paul Touchet
1	DRDME-VU, Paul Gatza
1	DRDME-GS, Charles Browne
	Director, U. S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland 21005
1	ATTN: DRDAR-TSB-S (STINFO)

No. of Copies	To
	Commander, Rock Island Arsenal, Rock Island, Illinois 61299
1	ATTN: SARRI-ENM, William Garland
	Commander, U. S. Army Foreign Science and Technology Center, 220 7th Street, N.E., Charlottesville, Virginia 22901
1	ATTN: Mr. Marley, Military Tech
	Commander, U. S. Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, Maryland 21005
1	ATTN: DRXSY-MP, H. Cohen
	Naval Research Laboratory, Washington, D. C. 20375
1	ATTN: Dr. J. M. Krafft - Code 8430
	Chief of Naval Research, Arlington, Virginia 22217
1	ATTN: Code 471
1	Chemistry Program, Kenneth J. Wynne
	Department of the Navy, Naval Ship R&D Center, Annapolis Laboratory, Annapolis, Maryland 21402
1	ATTN: M. L. Sherman, Code 2842
1	W. M. Widenor, Code 2843
	Department of the Navy, Naval Ship Engineering Center, Washington, D. C. 20362
1	ATTN: 6101E, John Alfers
	Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio 45433
2	ATTN: AFML/MXE/E. Morrissey
1	AFML/LC
1	AFML/LLP/D. M. Forney, Jr.
1	AFML/MBC/Stanley Schulman
1	AFML/MBE/R. E. Headrick, Nonmetallic Materials Division
	Wright-Patterson Air Force Base, Ohio 45433
1	ATTN: ASD-YYEFS, F. S. Owens
	National Aeronautics and Space Administration, Washington, D. C. 20546
1	ATTN: Mr. B. G. Achhammer
1	Mr. G. C. Deutsch - Code RW
	National Aeronautics and Space Administration, Lewis Research Center, 21000 Brookpark Road, Cleveland, Ohio 44135
1	ATTN: Dr. Tito T. Serafini
	National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Alabama 35812
1	ATTN: R. J. Schwinghamer, EH01, Director, M&P Laboratory
1	Mr. W. A. Wilson, EH41, Building 4612

No. of
Copies

1 Mechanical Properties Data Center, Belfour Stulen, Inc.
13917 W. Bay Shore Drive, Traverse City, Michigan 49684

Director, Army Materials and Mechanics Research Center,
Watertown, Massachusetts 02172

2 ATTN: DRXMR-PL
1 DRXMR-PR
1 DRXMR-PD
1 DRXMR-AP
1 DRXMR-R, Dr. G. Thomas
1 DRXMR-RA, Dr. W. E. Davidsohn
5 DRXMR-RA, Dr. R. E. Singler